Optimizing a Functional Snack for Clinical Trials: Soy and Safflower Soft Pretzels

Thesis

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By

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Abstract

Consider the calorie dense, nutrient poor, soft pretzel commonly enjoyed at sports events and shopping malls. By the inclusion of safflower oil and soy ingredients, pretzels can be a nutrient and phytochemical rich snack food. The primary aim of the study was to investigate the inclusion of safflower and soy into a pretzel formulation acceptable for clinical trials. Formulations were assessed based on clinical dosage of soy and safflower ingredients in addition to pretzel quality. Instrumental surrogates of pretzel quality (texture profile analysis, crumb moisture, and un-freezable water) were evaluated by comparing soy and safflower pretzels to control, wheat pretzels. Soy ingredients (3:1, soy flour:soymilk) were analyzed at 30, 40, and 50% (dry basis) while safflower oil was tested at 10, 20, and 30% of the pretzel formulation. Pretzel replicates (n=9) from three separate batches per formulation were frozen and thawed before testing. The physicochemical properties of pretzel samples were characterized using a thermo-gravimetric analyzer to measure moisture content, differential scanning calorimeter to measure freezable (FW) and un-freezable (UFW) water, and Instron (texture profile analysis) to measure crumb texture. Results showed that as soy concentration increased, measures of UFW and hardness increased. The increase in UFW retards pretzel staling while crumb hardness diminishes the sensory quality of the pretzels. As safflower oil concentration increased, pretzel hardness decreased. Safflower oil did not impact FW or UFW. Therefore, the 40% soy and 30% safflower pretzel formulation was chosen as the best compromise of UFW and hardness as well as a sufficient dosage vehicle in dietary intervention trials. Future sensory trials will be used to confirm the acceptability of this formulation and to finalize the formulation for use in clinical trials investigating the impact of soy ingredients and safflower oil pretzel snacks in obese women with metabolic syndrome.

Acknowledgements

I would like to thank Dr. Yael Vodovotz for welcoming me into her research group and for allowing me to work on this project. Being a part of her group has given me the opportunity to see what research is all about and to learn from the other members of her group. It has been an invaluable experience. I would also like to thank Dr. Jennifer Ahn-Jarvis for her hands on guidance, instruction, and mentorship throughout my time working on this project. This project would not have been possible without her continued direction and support. Finally, I would like to thank Dr. Dennis Heldman for being on my thesis committee and for his wise advice. This work was supported by the College of Engineering Undergraduate Research Scholarship Fund.

Curriculum Vita

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1. Literature Review

1.1 Snacking Behavior and Obesity in the US

Over the span of 1977 to 2006, American children increased their consumption of salty snacks, sweetened caloric beverages, and candy to account for over a quarter of their daily intake[4]. These snacks tend to be high in sugar or salt as well as low in essential nutrients and in phytochemicals. The routine consumption of these foods from childhood into adulthood increases the risk for chronic diseases such as cardiovascular disease, type 2 diabetes, and cancer[5].

Chronic diseases such as heart disease, cancer, diabetes, and obesity are among the most common, costly, and preventable of all health problems[1] in the United States and most Western countries[2]. These diseases are preventable because they are, in many cases, greatly attributable to diet[2]. The first and second leading causes of death in America are cardiovascular disease and cancer; both of these diseases can be caused by nutritional factors including obesity[2]. Recommendations for healthier lifestyles including diets, high in fruits and vegetables, and regular exercise have not yet been effective in changing the rates of chronic diseases in Western countries[3].

A solution that may prove more effective than lifestyle alterations is to modify popular Western snack foods in order to be health promoting rather than disease promoting. One possible strategy is to integrate nutritious ingredients such as safflower oil and soy ingredients into a convenient snack such as a soft pretzel commonly found at sports events and shopping malls.

1.2 Health Benefits of Safflower Oil

Safflower oil contains large amounts of the polyunsaturated fatty acid, linoleic acid and its polyunstaturated/saturated index is very high[17]. The healthy ratio of essential fats makes this oil ideal for mass consumption[17].

A 16 week clinical study found that daily supplementation of 8 grams of safflower oil, in the diet of 35 postmenopausal women with type 2 diabetes, resulted in reduced trunk adipose tissue, increased lean mass, lowered fasting glucose, and increased adiponectin[6]. Researchers concluded that small changes in dietary fat quality may decrease risk factors for diabetes-related complications. Another clinical study on the same population type, found that dietary supplementation of safflower oil improved glycemia, inflammation, and blood lipids[7]. Both of these early studies indicate that risk factors for diabetes-related complications may be improved by incorporating safflower oil into the diet. An easy way to incorporate safflower oil into the diet, is by consuming it in snack foods that require a lipid source.

1.3 Health Benefits of Soy

Soy contains bioactive components, protein, fiber, all 20 amino acids, and isoflavones[5]. So many studies support soy protein lowering the risk of coronary heart disease that this is substantiated by a U.S. Food and Drug Administration (FDA) claim[8]. The fiber and isoflavones in soy may also contribute to cardiovascular benefits, but the specific molecular components responsible for the benefits are unclear[9].

In 2012, Ahn-Jarvis et al. compared the effects of food matrix (bread versus beverage) on the metabolism of soy in adult men and women with hypercholesterolemia[15]. The findings suggest that food matrix does influence soy metabolism in women. Men, however, metabolized the soy in bread and beverage without significant variation. Besides soy metabolism, this study showed that blood lipid values were improved over the ten week study. The fact that a modest addition of soy (less than the FDA claim of 25 grams per day) significantly improves lipids in the diet of a population predisposed to high blood lipids, exemplifies soy's ability to reduce risk factors for cardiovascular disease.

In 2011, Simmons et al. replaced 27.3% of wheat flour with soy ingredients in a soft pretzel. The pretzels were first tested for consumer acceptability by 51 untrained sensory panelists on a 9-point hedonic scale. The soy pretzels were then compared to wheat pretzels on their ability to produce a change in satiety, glycemic index, and insulinemic index in a crossover clinical trial of 20 healthy adults[5]. Satiety was evaluated on a 10 centimeter visual analog scale (VAS) for 2 hours postprandially[5]. Blood glucose and insulin responses were monitored for 2 hours after consumption and compared to a glucose reference[5]. Results showed that soy pretzels had a lower glycemic index than wheat pretzels[5]. The addition of soy did not have a significant effect on satiety or insulinemia. These results show that it is possible to supplement a variety of snack foods with soy at high enough quantities to achieve lower postprandial glycemia while maintaining favorable sensory characteristics.

Soy has been shown to reduce cardiovascular risk as well as avoid insulin spiking, a concern for diabetics in particular. In addition, soy ingredients can be manipulated to partially replace the wheat flour in bread systems, such as pretzels, and can therefore be conveniently integrated into a Western diet[10].

1.4 Impact of High-dose Safflower Oil in Baked products

During bread baking, the gluten network in dough transforms into a continuous, permanent network while gas cells expand[19]. This phenomenon is aided by the coating of gluten strands in hydrogenated fats (at approximately 4% of the formulation or less) and therefore enhances loaf volume. Lipids are known to improve the storage quality of bread[19]. A probable explanation is that the fats form a barrier to moisture migration in the crumb and therefore prevent the bread from drying out[19].

High inclusion of fats, however, has very different effects from those described in the paragraph above. High fat provides shortened crumb structure and foam stabilization, as well as cake-like sensory characteristics: moistness, tenderness, lubricity, and cohesiveness[20]. This is not necessarily desirable for pretzels. When oil is substituted for shortening, volume and total moisture decrease[20]. Safflower oil is similar to other vegetable oils in regard to its sensory characteristics, as well as in its performance in bread systems. Therefore, this oil can be incorporated into a soft pretzel with little alteration of the base formula.

1.5 Impact of High-dose Soy Ingredients in Baked products

The use of soy in bakery products has been limited because of unacceptable sensory and textural properties[12]. In 2002, Dhingra and Jood measured the organoleptic properties of soy breads compared to wheat breads with regard to crust color, appearance, flavor, crust texture, taste and overall acceptability[18]. These properties were judged by a sensory panel using a 9-point hedonic scale. Traditional wheat bread received average ratings of 7.7 for all categories. Breads mixed with soy had darker crusts resulting in a hedonic reading of 5.6 for the breads made with an 80% wheat 20% soy flour mixture[18]. Flavor was also rated worse (as low as 4) for the 20% soy bread compared to the traditional. Researchers attributed this to the ‘beany’ flavor imparted by soy flour[18]. Breads with 10% soy, however, were considered to be overall acceptable. Therefore, high levels of soy in breads are known to diminish quality.

In 2006, Vittadini and Vodovotz studied physicochemical property changes in wheat bread when soy ingredients are added to the bread formulation. Soy was found to influence the quality of the breads in the following ways: increase in soy was correlated with an increase in loaf density, moisture content and freezable water content, and a decrease in amylopectin recrystallization[12].

One of the primary instruments of analysis was the Differential Scanning Calorimeter (DSC), which monitors phase transitions within a material as a function of temperature. Phase transitions, such as freezable water and amylopectin recrystallization, are important in bread studies because freezable water decreases and crystalline amylopectin increases with storage[12]. These trends denote the staling process. When monitoring the shelf life of wheat bread, and wheat breads with 20, 30 and 40% soy ingredients (dry basis), staling was slowed with increasing amounts of soy in the formulations. Therefore, soy has a positive function of prolonging the shelf life of breads. Soy caused an increase in freezable water content and a decrease in temperature of thermal transition of water measured using a DSC[12]. In addition to decreased staling, this demonstrates a change in water behavior in bread when soy is included.

Loaf density was measured using a rapeseed displacement apparatus. Density of the bread loaves increased with an increase in soy flour addition[12]. Higher bread density (decreased specific loaf volume) has been correlated to increased firmness in the bread[12].

In conclusion, the literature shows that snacking, obesity and the related chronic diseases are on the rise in the U.S. Also, the functional ingredients from soy and safflower have significant health benefits. The inclusion of these ingredients can greatly enhance the nutritional quality of snack foods like soft pretzels. Thus far, high doses of these ingredients in bread products causes decreased sensory appeal but increased shelf life. Therefore, the success of this healthy snack relies on the quality optimization of soy and safflower pretzels.

2. Problem Identification and Justification

The challenge of adding soy ingredients and safflower oil to a traditional wheat pretzel is that these ingredients change appearance, texture, and flavor of this traditional snack. For this study, pretzels need to contain clinical doses of both functional ingredients. The pretzels must also meet quality requirements so that 20 postmenopausal women with metabolic syndrome will consume them, willingly, during a 14 week clinical study. Once the formulation satisfies these goals, this new pretzel delivery system can be investigated for its health benefits without greatly altering the diet or lifestyle patterns of the participants in the trial. A final consideration for optimizing the quality of the pretzel formulation is for the future commercialization of a functional snack. The product will have the greatest impact on public health if it is available to the average consumer and consumed outside of prescription.

There are many technical difficulties associated with substituting soy ingredients for wheat flour. Currently, commercial soy products similar to bread have much denser crumb structures than commercial wheat products. This is because soy products do not properly develop a gluten network during processing. Proper gluten development, as well as a patented soy flour to soy milk mixture, allows for the texture of the soy product to be light and springy rather than dense. The proposed pretzel reformulation is based on Patent 10/267,845, a processing method for soy bread which allows for the final texture of soy bread to be comparable to wheat bread[11]. In addition, it has been shown, through sensory tests, that soy ingredients can be successfully added to a soft pretzel without affecting consumer acceptability[5].

2.1 Objectives

The primary objective of this thesis is to optimize a soy and safflower pretzel formulation to be comparable, in terms of quality, with typical wheat pretzels while maximizing the dose of soy and safflower per pretzel. Quality will be based on measures of pretzel texture, moisture, free water, color, volume, and density. The samples with results closest to that of a control wheat pretzel will be evaluated by a sensory panel.

A formulation with 40% soy and 20% safflower is hypothesized to be the most successful formulation. This formula was chosen because it will supply the clinical dose while hypothetically maintaining acceptable texture. The soft pretzel formula, which best meets the criterion for dosage and quality, will be used in clinical trials to investigate the disease preventing and weight management effects of soy and safflower in a soft pretzel delivery system.

3. Materials and Methods

3.1 Overview: Study Design

A systematic approach of varying soy and safflower ingredients was performed during the 2014-2015 academic year. The study design is laid out in figure 1.

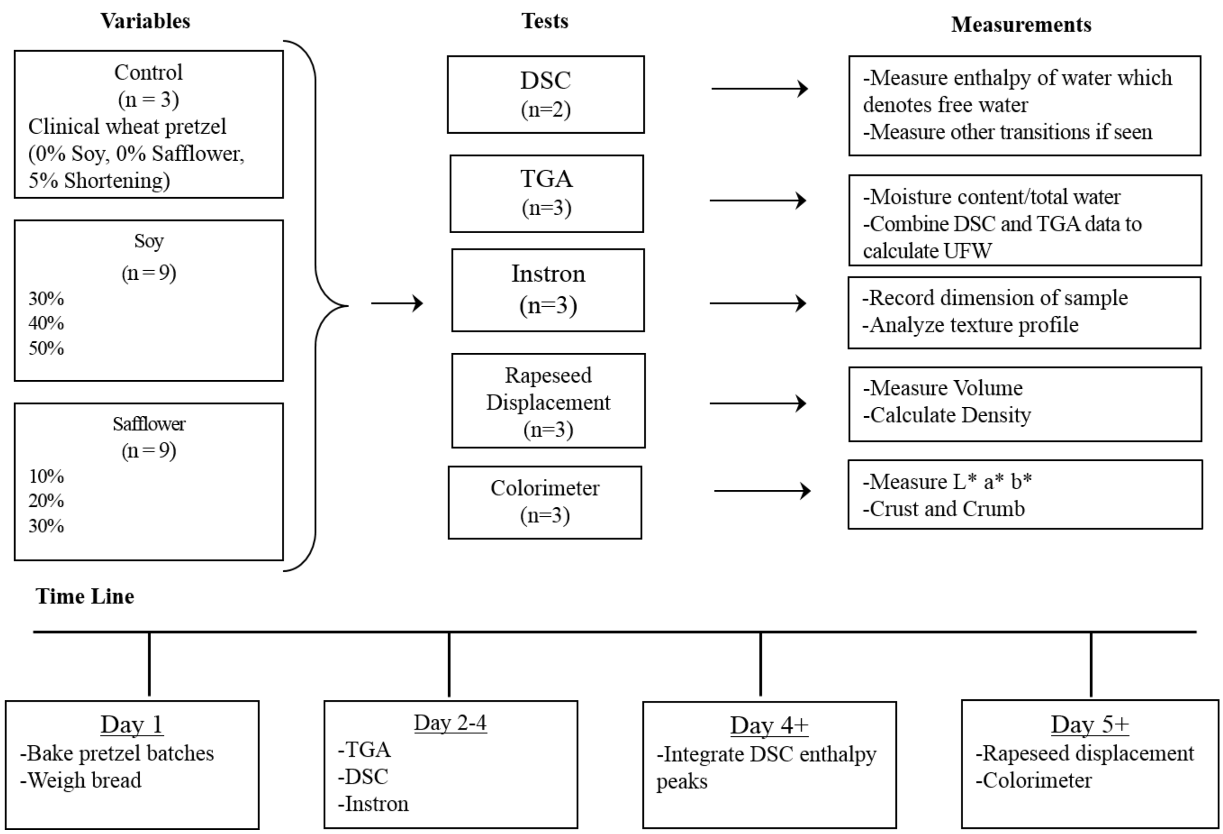

Figure 1: Conceptual Frame

The pretzel formulations were varied with regard to the level of soy ingredients and safflower oil. Three batches of each formula were baked to account for variability.

To mimic pretzel quality after storage conditions for clinical trials, pretzel samples were frozen and thawed before testing. To control for changes in water chemistry and crumb structure during staling, the samples were tested within 4 days of baking for moisture content, free water, and texture profile. Color and volume can be tested at any time during the study.

The samples whose quality measurements were closest to the control wheat pretzels will be selected for a sensory trial. The sensory trial results will be considered when choosing the final formulation for the clinical trial.

3.2 Materials

The ingredients (% dry basis) for the soy and safflower soft pretzel formulations are displayed in Table 1. Water was used at 30% wet basis in each formula.

Table 1: Ingredients and formulations by % dry basis

Ingredients	Manufacturer	% dry basis					
		Wheat Control	30% Soy	40% Soy 20% Saff	50% Soy	10% Saff	30% Saff
Water	–	0					
Bread Flour	Bay State Milling Co., Quincy, Mass., U.S.A.	81.60	43.74	33.74	23.74	43.74	23.74
Wheat gluten	Bob's Red Mill, Milwaukie, Oreg., U.S.A.	1.31					
Soy Flour	ADM, Decatur, Ill., U.S.A.	0.00	22.50	30.00	37.50	30.00	30.00
Soymilk powder	Devansoy, Carroll, Iowa, U.S.A.	0.00	7.50	10.00	12.50	10.00	10.00
Sugar	Food Service, Grand Rapids, Mich., U.S.A.	2.71					
Lipid	Safflower Oil: The Hain Celestial Group, Inc. Boulder, CO 80301 USA Shortening (in wheat control only): The J.M. Smucker Co., Orrville, Ohio, U.S.A.	5.00	20.00	20.00	20.00	10.00	30.00
Yeast	Lallemand, Montr´eal, QC, Canada	1.03					
Salt	U.S. Foodservice, Columbia, Md., U.S.A.	1.03					
Dough conditioner	Caravan Ingredients, Lenexa, Kans., U.S.A.	0.17					

3.3 Methods

3.3.1 Pretzel preparation

The pretzel formulations were made using a sponge-dough method from the Patent: Compositions and Processes for Making High Soy Protein-Containing Bakery Products[14]. First a sponge was made from water, bread flour, wheat gluten, yeast, and salt. The yeast was hydrated in warm water for at least 5 minutes before being used in the sponge. The dry ingredients were mixed together with water in a blender with the beater attachment for 7-10 minutes until pale white in color and easily separable from the mixing bowl. The sponge was allowed to ferment for 30 minutes. A dough was made from water, soy flour, soymilk, sugar, lipid, yeast, salt, and dough conditioner. Before mixing, the sponge was added to the dough. The dough was mixed with the hook attachment for 7-10 minutes until the ingredients were homogeneous and the dough held together. The dough was portioned into pretzel sticks on a baking sheet and proofed for 15 minutes at 105°F. Typically, before proofing, pretzel doughs are dipped in a lye bath or boiling water. This step was omitted in these experimental methods because this step causes a color change in the pretzels that masks color change due to safflower and soy ingredients. In this study, color is a measure that was experimentally attributed to ingredient changes. The pretzels were baked for 10 minutes at 325°F in a convection oven. The pretzels cooled at room temperature for 1.5 hours before being placed in polyethylene bags and frozen. Samples were analyzed within 4 days of baking. Samples thawed in ambient conditions on the day of analysis of moisture content, phase transitions between -50 and 180°C, and texture profile. Since volume and color were not significantly affected during frozen storage, these measures were evaluated outside of the 4 day mark.

3.3.2 Differential Scanning Calorimeter (DSC)

Phase transition of water was examined using a Differential Scanning Calorimeter Q100 (TA Instruments, New Castle DE). Crumb samples of 10-20 milligrams were placed in stainless steel pans (PerkinElmer Life and Analytical Sciences, Inc.) and hermetically sealed with an O-ring (PerkinElmer, Boston, MA). Empty reference pans were made on each analysis day. The samples were cooled to -50°C and heated to 180°C at 5°C per minute. The percent freezable water (FW) was calculated after integrating the endothermic peak near 0°C using the following expression[12].

$$\%\ \mathrm{FW} = \frac{(\text{peak enthalpy})(\text{g sample})}{(\text{Latent heat of fusion of ice})(\text{g total moisture content})} * 100$$

The percent un-freezable water (UFW) was calculated from the difference of percent freezable water from percent total moisture content, determined from Thermogravimetric analysis.

3.3.3 Thermogravimetric Analyzer (TGA)

The total moisture contents of the pretzel samples were measured using the Thermo-gravimetric Analyzer Q5000 (TA Instruments, New Castle DE). Crumb samples of 10-15 milligrams were placed on platinum pans (PerkinElmer Life and Analytical Sciences, Inc., Boston, Mass., U.S.A.) and analyzed as quickly as possible to avoid unrecorded water loss to the environment. The chamber was equilibrated at 25°C and heated to 180°C at 10°C per minute. Water loss was measured from the outputted derivative weight loss curve.

3.3.4 Texture Profile Analysis (TPA)

The Instron Universal Testing Machine 5542, Bluehill 2 software version 2.17 was used to determine hardness, springiness, chewiness, and adhesiveness of the crumb of the pretzel samples. The procedure was modified from the American Association of Cereal Chemists (AACC) method 74-09[15]. Samples were uniaxially compressed by 40% with a crosshead speed of 100 millimeters per minute to mimic mastication[16]. Crumb from the center of the pretzel sticks was cut to the dimensions of 1 inch cube.

3.3.5 Specific Loaf Volume

Loaf mass (g) was determined from freshly baked samples after a 1.5 hour cooling period. A rapeseed displacement apparatus was used to measure the volume and subsequently specific loaf volume (cc/g) of pretzel samples using the AACC method 10-05[15].

3.3.6 Color

The crust and crumb color of the samples was measured using a Chroma Meter CR-300 (Konica Minolta Sensing Americas, Inc., Ramsey, N.J., U.S.A.). This equipment supplied values that describe a color space with coordinates specified as L, a*, and b*. Lightness (L) ranges from 0 (black) to 100 (white), a-value (a*) ranges from -120 (green) to +120 (red), and b-value (b*) ranges from -120 (blue) to +120 (yellow). A calculated color parameter, called the browning index (BI), was used to evaluate the samples' color attributed to non-enzymatic browning taking place during baking[13]. The formula for BI is given below:

$$\mathrm{BI} = \frac{100 * (\mathrm{X} - 0.31)}{0.17}$$

Where: $$X = \frac{a + (1.75 * L)}{(5.645 * L) + a - (3.012 * b)}$$

Another color parameter that can be calculated from L, a*, and b* values is Chroma, a descriptor of color intensity.

$$\mathrm{Chroma} = \sqrt{\mathrm{a}^{*2} + \mathrm{b}^{*2}}$$

3.3.7 Statistical Analysis

ANOVA analysis was conducted to determine statistical differences with a p-value, $p \leq 0.05$. Results are reported as mean ± standard deviation.

4. Results and Discussion

4.1 Thermal Analysis

4.1.1 Differential Scanning Calorimeter (DSC)

The thermal analyses showed significant differences between pretzel formulas. When looking at the Differential Scanning Calorimeter thermograms in Figure 3, definite differences were noted with respect to the water melt peaks in the wheat control and soy modulated formulas. As soy concentration increased, the enthalpy of water peaks were further depressed from zero. The freezing point depression lends to the theory that increasing soy concentrations increases the ability of a bread system to bind water. An increase in bound water is expected to deter pretzel staling[12]. Freezing point depression may not give the complete picture with regard to bound and unbound water, but it certainly shows a trend in the behavior of water in pretzels with increasing concentrations of soy.

Table 2: Thermogram enthalpic water peaks of wheat and soy pretzels

Pretzel Variables	Onset	Peak	End
Soy 50%	-27.85	$-5.43^{a} \pm 1.01$	5.45
Soy 40%	-25.28	$-4.66^{ab} \pm 0.49$	5.23
Soy 30%	-26.15	$-3.77^{b} \pm 0.57$	7.89
Wheat Control	-19.1	$-1.91^{c} \pm 0.80$	7.52

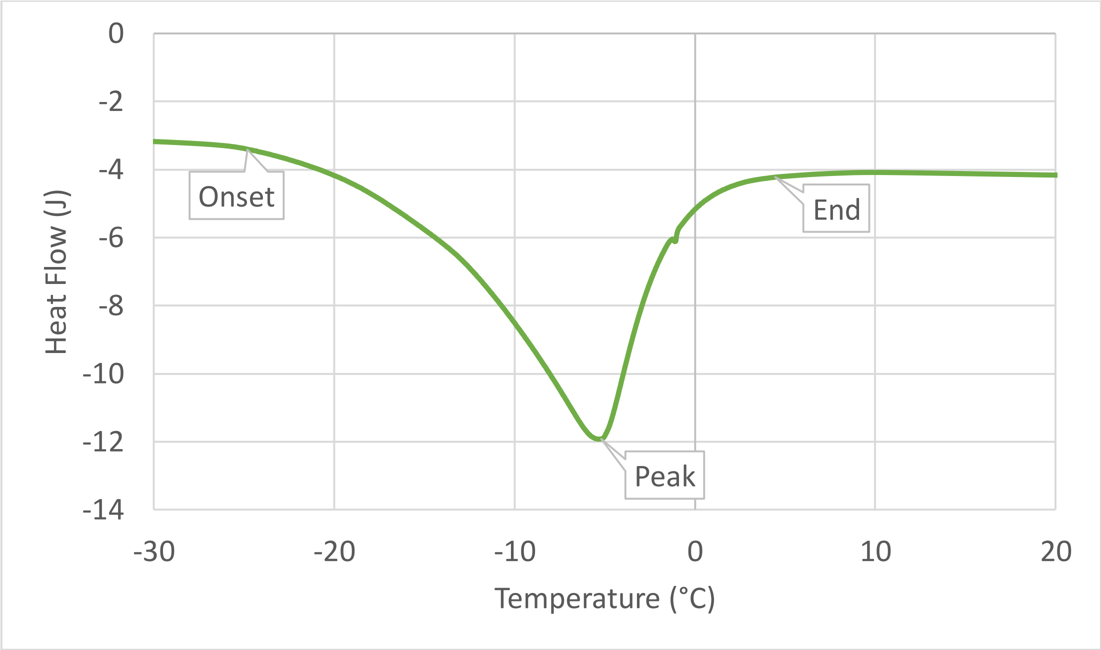

Figure 2: Reference for onset, peak and end of enthalpic peak of water

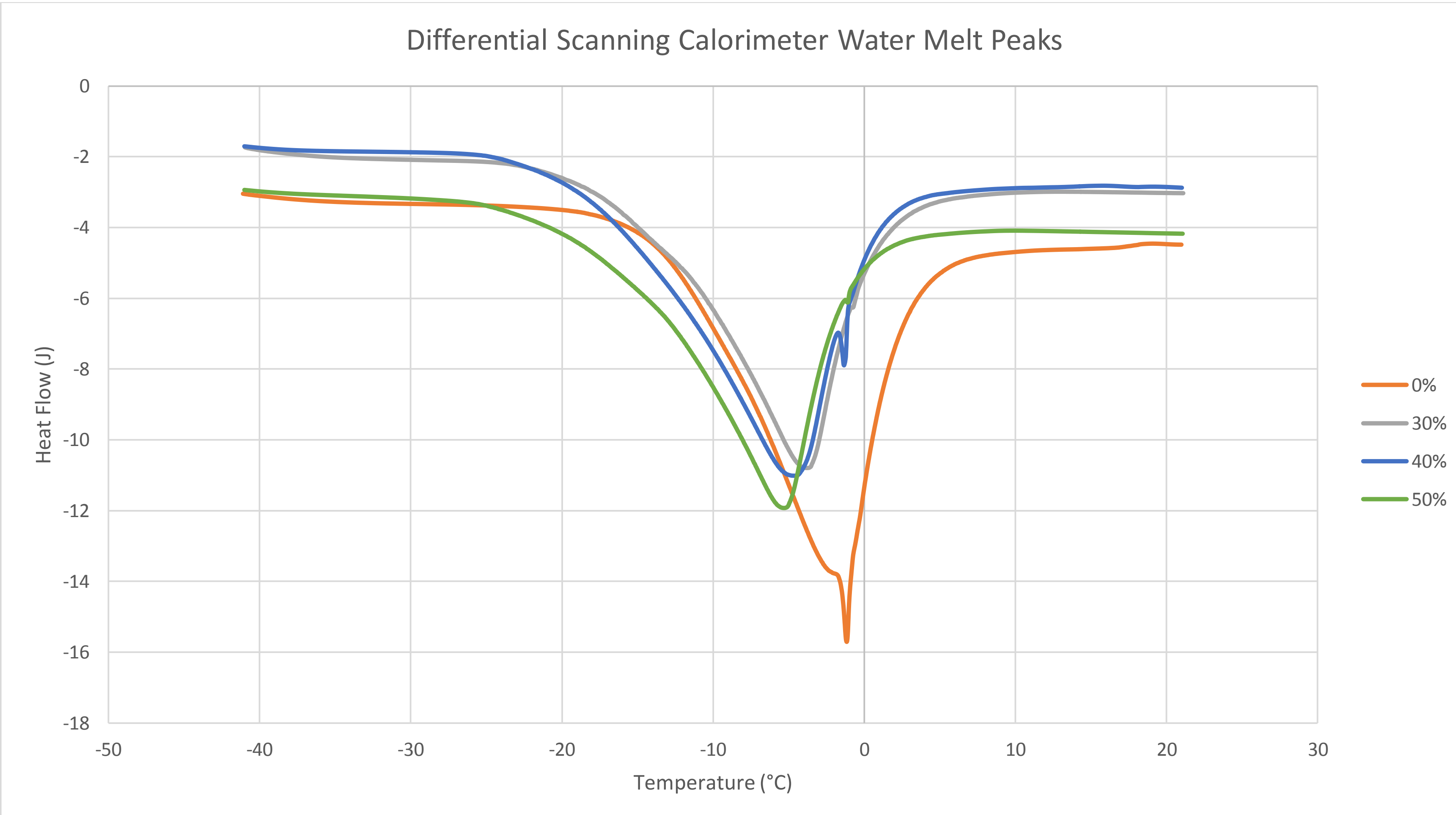

Figure 3: Thermograms of pretzel samples with increasing soy concentrations

4.1.2 Thermogravimetric Analyzer (TGA)

The thermogravimetric analyzer showed that wheat pretzels had a higher total water content than the soy and safflower pretzels. The literature supports that wheat bread systems are moister than soy bread systems. If more replicates were done, it may have been possible to decipher a steeper indirect relationship between soy concentrations and total moisture content.

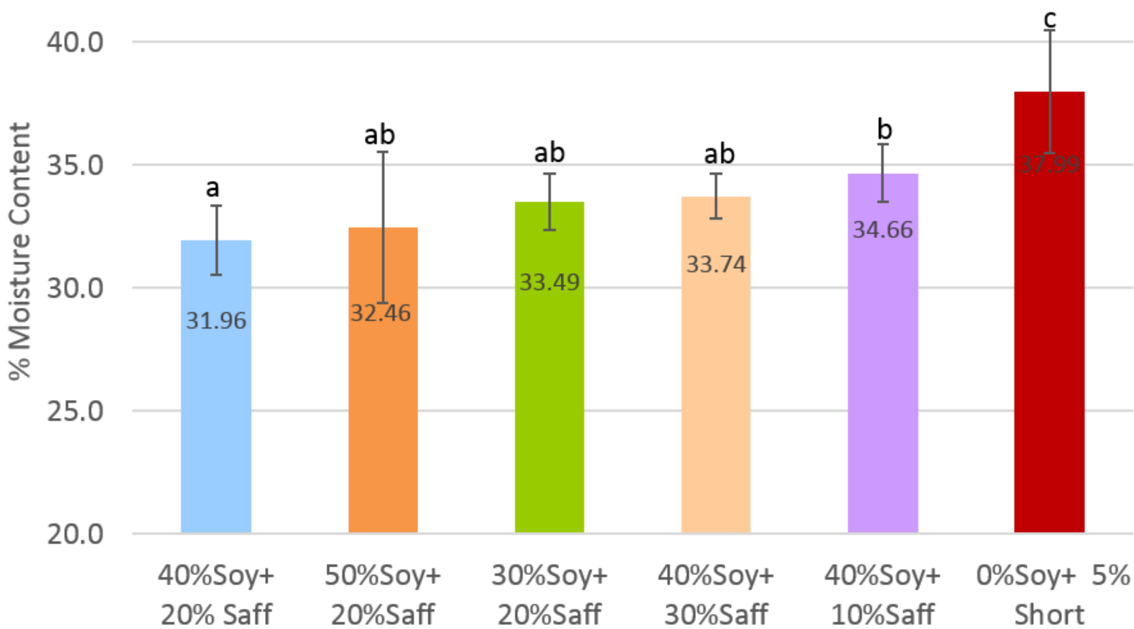

Figure 4: Moisture content across all formulas

4.2 Physical Analysis

4.2.1 Texture Profile Analysis (TPA)

Texture profile analysis from the Instron showed interesting texture distinctions between all formulas with regard to the springiness. This confirms that changes in ingredients causes significant quality changes in the end product.

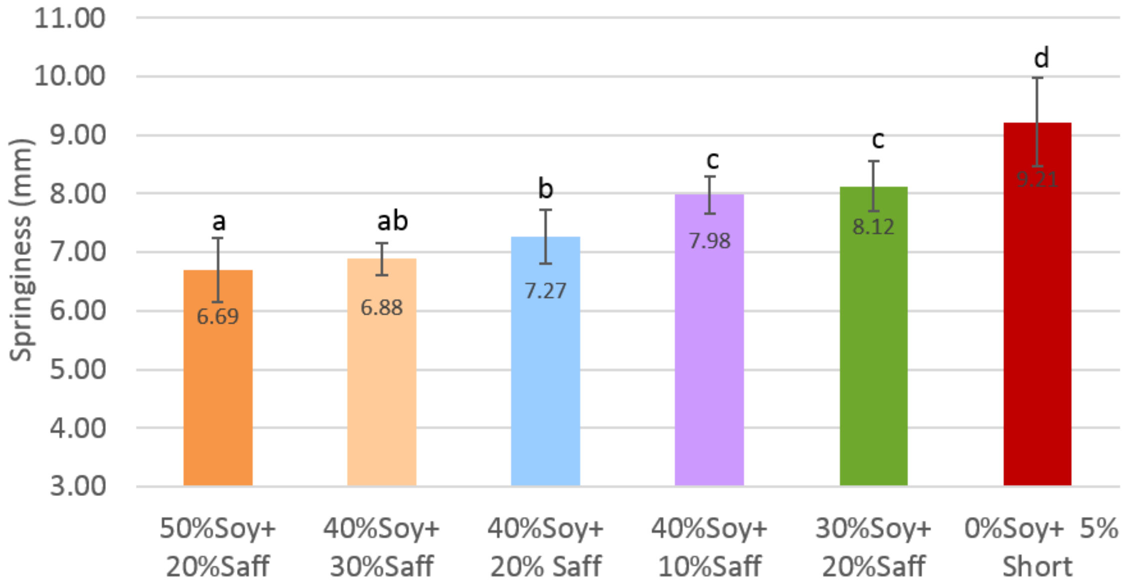

Figure 5: Springiness across all formulas

Though all formulas are different in texture as denoted by the measure of springiness, texture similarities can be found when looking at the texture measure of hardness. It can be seen from the hardness data in Figure 6 that as soy concentration increases, hardness increases. Crumb hardness diminishes the quality of the soft pretzels. However, as safflower oil concentrations increase, hardness decreases. Therefore, a high dose of safflower and soy ingredients can be achieved while maintaining optimal pretzel hardness. Since the hardness of the 40% soy 30% safflower formulation is not significantly different in texture from the control wheat pretzel, it was determined that this formulation provided a compromise of high dose and similar texture quality to typical wheat pretzels.

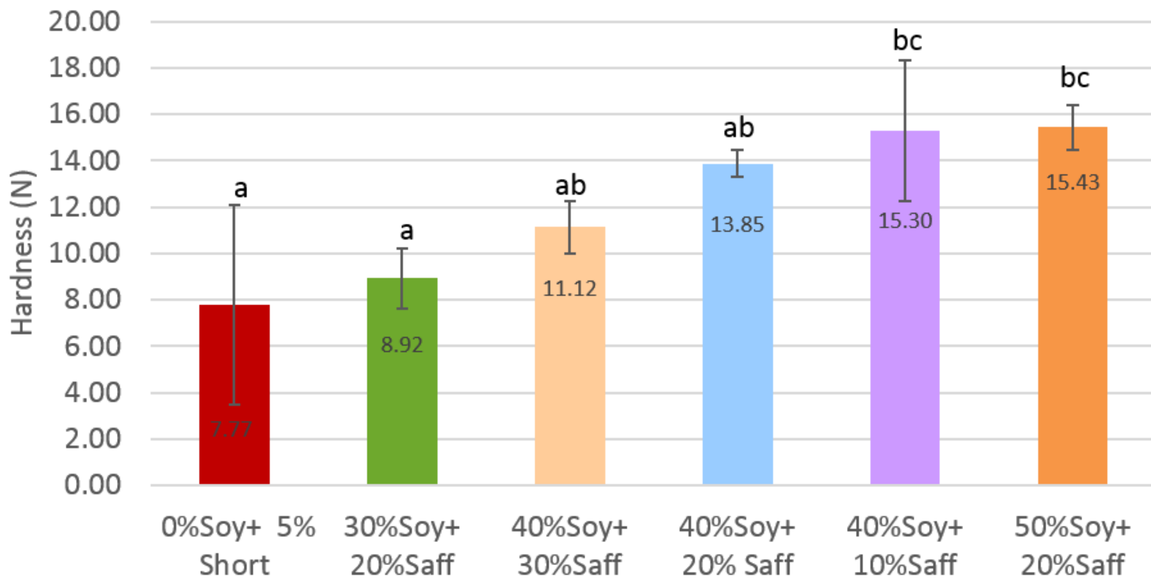

Figure 6: Hardness across all formulas

4.2.2 Specific Loaf Volume

Specific volumes were shown to be different between the control wheat pretzels and the soy and safflower pretzels. Figure 7 and Figure 8 show that when looking at the soy and safflower categories as they compare to the wheat control, there is a distinction in specific volume. It was expected, through observation of samples, that a trend between soy concentration and decreasing specific loaf volumes would become apparent. This data only shows a distinction between the control and the other formulas. This may be attributed to the fact that the volumes were measured close to the limits of volumes measureable with the Rapeseed Displacement used in this analysis.

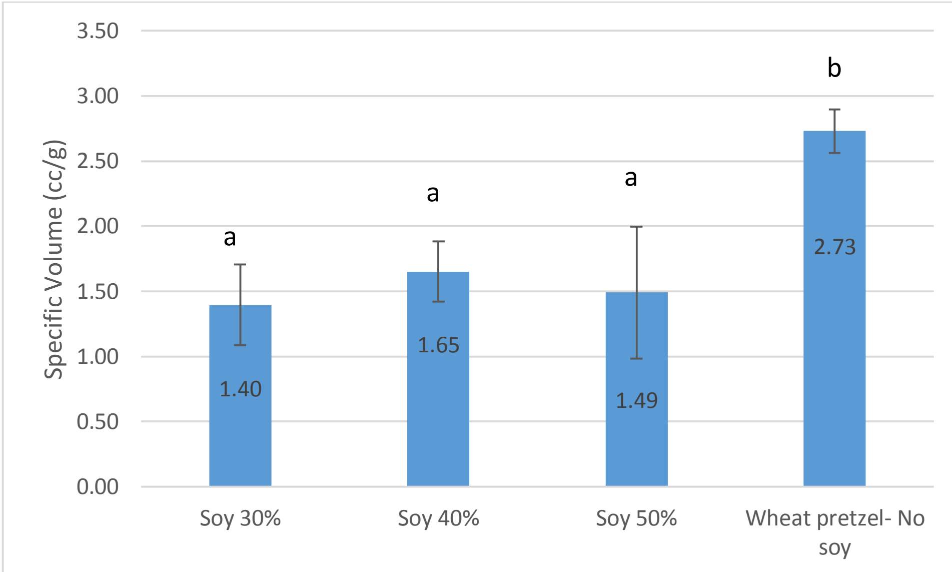

Figure 7: Specific Volume (cc/g) of soy modulated samples

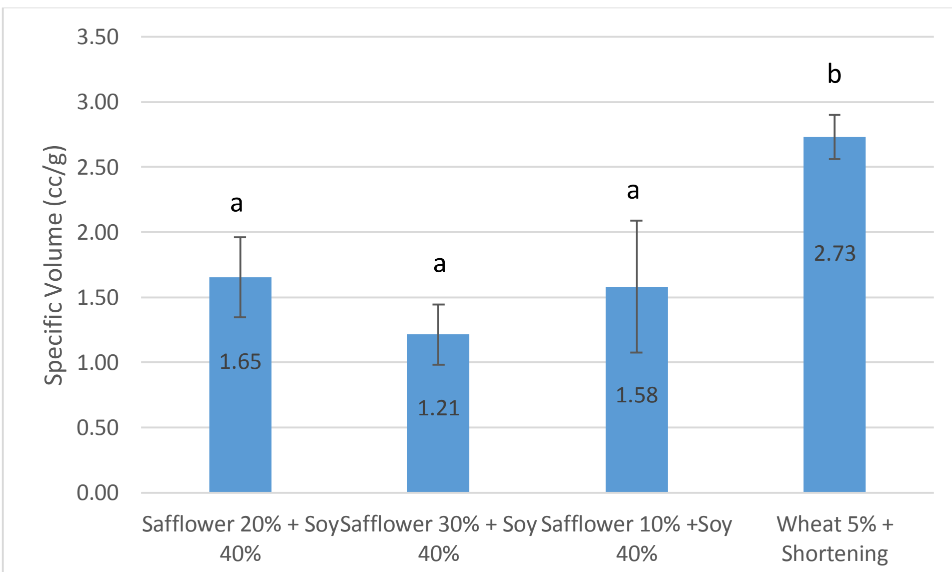

Figure 8: Specific Volume (cc/g) of safflower modulated samples

4.2.3 Color

Brownness in the crumb was most notably modulated by the soy content while brownness in the crust was modulated by the oil content as noted by the values in Figure 9. Since the crumb is protected from the heat and convection that causes Maillard Browning on the crust, the color of the crumb can be attributed more exclusively to the ingredients than possible fluctuations in baking conditions.

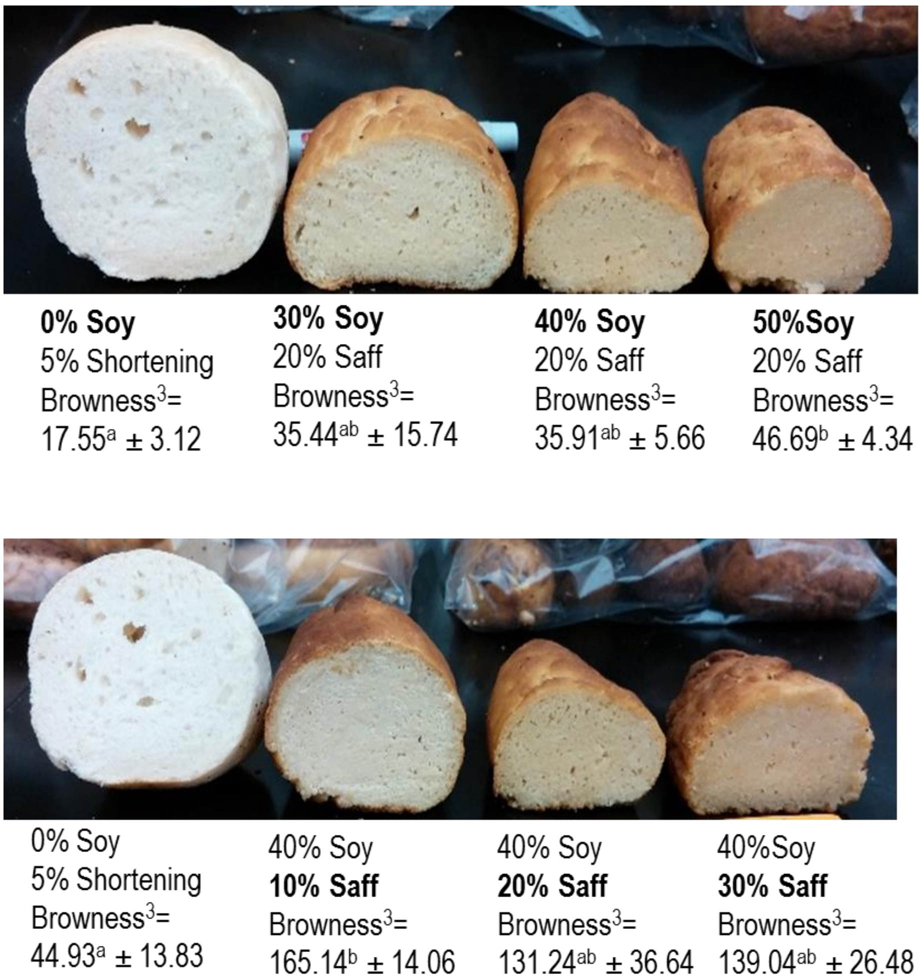

Figure 9: Browning Index (BI) of soft Pretzels (Left shows BI of Crumb and Right shows BI of Crust)

Chroma in the crust was most notably modulated by the safflower oil content as seen in Figure 10. This trend may be attributed to Maillard Browning during baking. Since oil is a greater heat transfer medium, it is thought that higher rates of heat transfer, and therefore higher rates of browning, may be occurring on the surface of pretzels with higher concentrations of oil.

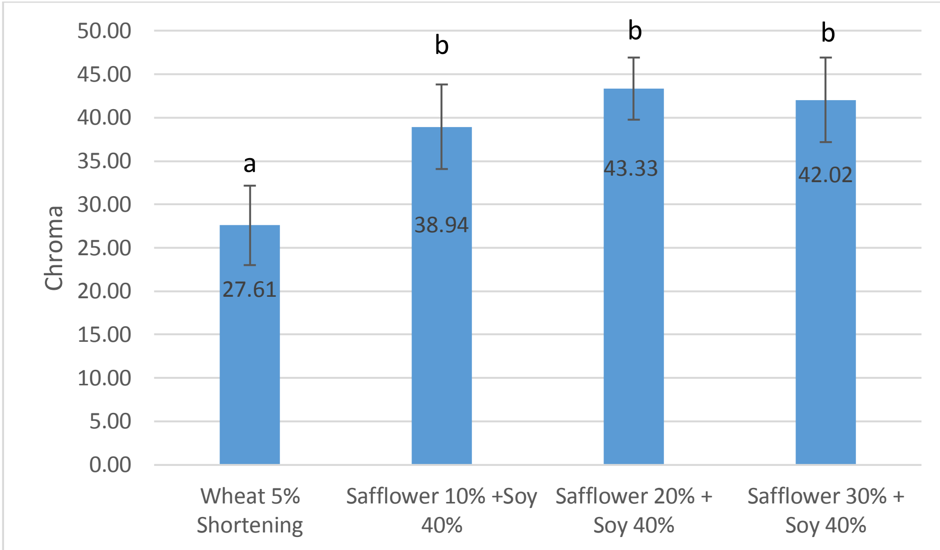

Figure 10: Chroma of soft pretzel crust across safflower oil formulas

5. Conclusion

There were several findings with regard to the functionality of soy and safflower ingredients in a soft pretzel system. First, as soy concentration increased, water melt temperature in the samples decreased and hardness increased. This illustrates the positive and negative factors associated with soy: longer shelf life yet diminished texture quality. Second, as safflower oil concentration increased, pretzel hardness decreased. Therefore, when developing a soy and safflower soft pretzel formulation, safflower oil counteracts the hardness changes caused by the soy ingredients. Third, the texture quality, described by springiness, differs from the control wheat pretzel formulation with both soy and safflower ingredients. The 40% soy and 30% safflower formulation was the best of the formulations tested in regard to the original objectives of quality and clinical dosage.

Future work will entail sensory evaluation to verify the acceptability of the chosen soy and safflower pretzel formulation. Based on the results of the sensory evaluation, further tweaking of the formula may be necessary to achieve the best possible formulation in regard to consumer satisfaction.

References

(1) Centers for Disease Control and Prevention. Chronic Diseases: The Leading Causes of Death and Disability in the United States, *2014*. Atlanta, GA: Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion; 2014. http://www.cdc.gov/chronicdisease/overview/#sec4 Accessed September 26 2014.

(2) Cordain, L.; Eaton, S.B.; Sebastian, A.; Mann,N.; Lindberg, S.; Watkins, B.A.; O'Keefe, J.H.; Brand-Miller, J. Origins and evolution of the Western diet: health implications for the 21st century. *Am J Clin Nutr* 2005, 81, 341-354.

(3) Vodovotz, Y.; Andridge, R.; Belury, M.A.; Schwartz, S.J.; Spees, C.; Yee, L.; Ahn-Jarvis, J.; Liu, L. Evaluation of functional snack foods containing safflower oil and soy on endpoints of energy metabolism in postmenopausal women with metabolic syndrome. 2014. Study Protocol.

(4) Piernas, C. and Popkin, B.M. Trends in Snacking Among U.S. Children. *Health affairs* 2010, 29, 398-404.

(5) Simmons, A.L.; Miller, C.K.; Clinton, S.K.; Vodovotz, Y. A comparison of satiety, glycemic index, and insulinemic index of wheat-derived soft pretzels with or without soy. *Food Funct.*, 2011, 2, 678

(6) Norris, L.E.; Collene, A.L.; Asp, M.L.; Hsu, J.C.; Liu, L.-.; Richardson, J.R.; Li, D.; Bell, D.; Osei, K.; Jackson, R.D.; Belury, M.A. Comparison of dietary conjugated linoleic acid with safflower oil on body composition in obese postmenopausal women with type 2 diabetes mellitus. *Am J Clin Nutr* 2009, 90, 468-476.

(7) Asp, M.L.; Collene, A.L.; Norris, L.E.; Cole, R.M.; Stout, M.B.; Tang, S.; Hsu, J.C.; Belury, M.A. Time-dependent effects of safflower oil to improve glycemia, inflammation

and blood lipids in obese, post-menopausal women with type 2 diabetes: A randomized, double-masked, crossover study. *Clinical Nutrition* 2011, 30, 443-449

(8) Food and Drug Administration, Health and Human Services Food labeling: health claims; soy protein and coronary heart disease: final rule. *Fed Reg* 1999, *64,* 57700-5773

(9) Xiao, C.W. Health Effects of Soy Protein and Isoflavones in Humans, *J. Nutr.*, 2008, 138, 1244S-1249S.

(10) Ahn-Jarvis, J.H. ; Riedl, K.M.; Schwartz, S.J.; Vodovotz, Y.; Design and Selection of Soy Breads Used for Evaluating Isoflavone Bioavailability in Clinical Trials. *J. Agric. Food Chem.* 2013, 61, 3111−3120

(11) Vodovotz et al. 2004. Compositions and Processes for making High Soy Protein-Containing Bakery Products. U.S. Patent 10/267,845, filed October 9, 2002, and issued April 15, 2004.

(12) Vittadini, E. and Vodovotz, Y. Changes in the Physicochemical Properties of Wheat- and Soy-containing Breads During Storage as Studied by Thermal Analyses. *Journal of Food Science*. 2003, 68, 2022–2027.

(13) Maskan, M. Kinetics of Colour Change of Kiwifruits during Hot Air and Microwave Drying. *Journal of Food Engineering*. 2001, 48, 169-175

(14) Vodovotz Y, Ballard C, inventors; The Ohio State Univ. Research Foundation, assignee. 2009 Sep 22. Compositions and processes for making high soy protein-containing bakery products.U.S. Patent 7,592,028 B2.

(15) AACC. 2000. Approved methods of the American Association of Cereal Chemists. 10th ed. St. Paul, Minn.: American Association of Cereal Chemists. p 1200

(16) Yezbick Y, Ahn-Jarvis J, Schwartz S, Vodovotz Y. Physicochemical Characterization and Sensory Analysis of Yeast-leavened and Sourdough Soy Breads. *Journal of Food Science*. 2013, 78, C1487-C1494.

(17) Kostik, Vesna and Memeti, Shaban and Bauer, Biljana Fatty acid composition of edible oils and fats. *Journal of Hygienic Engineering and Design*. 2013, 4, 112-116

(18) Dhingra S, Jood S. Organoleptic and nutritional evaluation of wheat breads supplemented with soybean and barley flour. *Food Chem.* 2001, 77, 479–88.

(19) Pareyt B, Finnie S, Putseys J, Delcour J. Lipids in bread making: Sources, interactions, and impact on bread quality. *Journal of Cereal Science*. 2011, 54, 266-279

(20) Sowmya M, Jeyarani T, Jyotsna R, Indrani D. Effect of replacement of fat with sesame oil and additives on rheological, microstructural, quality characteristics and fatty acid profile of cakes. *Food Hydrocolloids*. 2009, 23, 1827-1836